DEVELOPMENT OF FINITE ELEMENT CODE FOR NON-LINEAR ANALYSIS OF INTERLOCKING MORTARLESS MASONRY SYSTEM

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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TO ALL MEMBERS OF MY FAMILY

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Presently, interlocking mortarless masonry system has been developed as an alternative to the conventional mortared masonry system for wall construction. The structural behaviour of the interlocking mortarless masonry system is not well explored and there is no standard and/or design specification for safe design of the interlocking mortarless block masonry system. The existing finite element analyses are simplified due to the absence of the significant and essential structural characteristics of the interlocking mortarless masonry system. Hence these models show inaccurate prediction for the structural response of the masonry system compared to actual behaviour of the system found experimentally.

This study aims at investigating numerically the structural response of interlocking masonry system using finite element method. The developed algorithm used in the FE analysis includes appropriate mathematical models to simulate the main features of mortarless masonry system. These models are derived experimentally using small scale specimens. The main features simulated are the structural characteristics of the

interlocking dry joints under combined Normal-Shear force actions, the failure mechanism of the joints, nonlinear contact behaviour of the joint considering the geometric imperfection of the block beds, the nonlinear stress-strain behaviour of the masonry materials and the failure of the masonry materials as well as the geometric nonlinearity. Proper test setups have been proposed to measure accurately the joint response under elastic, inelastic and failure stages of load. The actual behaviour of the interlocking system obtained experimentally is mathematically modelled and implemented in the finite element algorithm developed for the analysis of the interlocking masonry system. An incremental-iterative 2-D nonlinear finite element code is developed to implement the proposed algorithm and analyze the masonry system till failure.

The developed experimental setups used in this study successfully revealed the important features of the interlocking mortarless joint. The results indicate that the developed constitutive model and finite element code can successfully trace the structural behaviour (capacity, deformation and mode of failure) of the interlocking mortarless masonry system from the initial stage of loading till the failure. A general equation is proposed to estimate the capacity of interlocking mortarless masonry walls under eccentric and concentric vertical loads.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN KOD UNSUR TERHINGGA UNTUK ANALISIS TIDAK LINEAR SISTM PERBATAAN TANPA MORTAR SALING-KUNCI.

Oleh

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Pada masa kini, sistem saling-kunci perbataan tanpa mortar telah dibangunkan sebagai alternatif kepada sistem perbataan dengan mortar yang biasa digunakan untuk pembinaan dinding. Tingkahlaku sistem struktur saling-kunci perbataan tanpa mortar belum dibangunkan dengan sempurna dan tiada piawaian dan/atau spesifikasi rekabentuk yang selamat untuk sistem perbataan blok saling-kunci. Analisis unsur terhingga yang sedia ada telah dipermudahkan kerana ketiadaan ciri penting sistem struktur perbataan tanpa mortar. Oleh itu model menunjukkan ketidaktepatan ramalan untuk tingkahlaku sistem struktur perbataan berbanding kepada tingkahlaku sebenar sistem yang dilakukan secara eksperimen.

Kajian ini bermatlamat untuk mengkaji tingkahlaku sistem struktur perbataan saling kunci secara numerikal menggunakan analisis unsur terhingga. Algorithma yang dibangunkan dalam analisis unsur terhingga merangkumi model matematik yang besesuaian, diperolehi secara eksperimen menggunakan spesimen yang berskala kecil. Penampilan paling utama yang disimulasikan adalah ciri struktur saling-kunci sambungan di bawah tindakan daya mampatan ricih, mekanisma kegagalan sambungan, ketidaklinearan tingkahlaku hubungan sambungan dengan mengambil kira ketidaktepatan blok secara geometri, ketidaklinearan tingkahlaku tegasan-terikan bahan bata, kegagalan bahan bata dan ketidaklinearan geometri. Ujikaji lengkap telah dicadangkan untuk mengukur secara tepat tindakbalas di bawah beban elastik, tidak elastik dan tahap kegagalan. Tingkahlaku sistem saling–kunci diperolehi secara eksperimen telah dimodelkan secara matematik untuk analisis sistem perbataan saling-kunci. Kod unsur terhingga 2-dimensi tak linear secara berperingkat telah dibangunkan dengan menggunakan algorithma yang dicadangkan dan menganalisis sistem perbataan sehingga gagal.

Susunan eksperimen yang dibangunkan untuk kajian telah berjaya membuktikan ciri penting sambungan saling-kunci sambungan tanpa mortar. Keputusan menunjukkan algrithma yang dibangunkan dan kod unsur terhingga telah berjaya mengesan tingkahlaku strukur (kapasiti, perubahan dan mod kegagalan) sistem saling-kunci perbataan tanpa mortar daripada peringkat awal bebanan hingga gagal. Persamaan umum diusulkan untuk menganggarkan kapasiti dinding perbataan saling kunci tanpa mortar di bawah bebanan tegak eksentrik dan konsentrik.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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